"to answer many of the fundamental biological questions; You must look at the thing! You will see the order of the bases in the chain; you will see the structure of the microsome. Unfortunately, the present microscope… is too crude. Make the microscope 100 times more powerful and the problems of biology would be made much easier"

Richard Feynman - 1959

- Objective

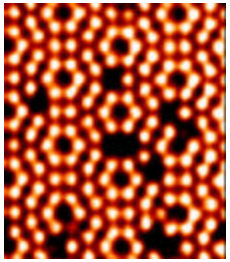
  Create a revolutionary new imaging capability for characterization of molecules, nanostructures and exotic materials with the following attributes

  - Atomic resolution
  - 3 dimensional reconstruction
  - Real time
  - Non-destructive
  - Molecular level control

Example of a Promising Technique

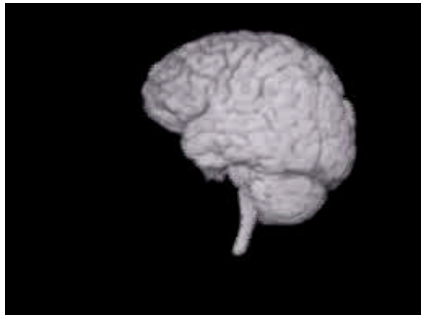
Atomic Force Microscopy

atomic scale, non-destructive, control
but only surface



Magnetic Resonance Imaging

3D, non-destructive
but macroscale

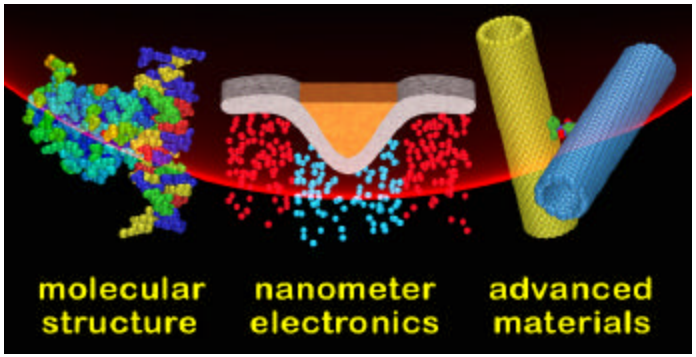


Technical hurdles

- Signal processing
- Nanofabrication
- Readout

Magnetic Resonance Force Microscopy

3D, atomic scale, non-destructive, and with control



Why Now

- Recent advances in the following areas of technology will enable the development of new tools to study atomic-scale structure of ***single molecules*** and nanoscale systems
  - *Micro-fabrication* of very large aspect-ratio cantilevers
  - Efficient *physics-based signal processing and control* methodologies
  - *Novel interferometric read out*
  - *High resolution structure* determination in biotechnology

M O S A I C

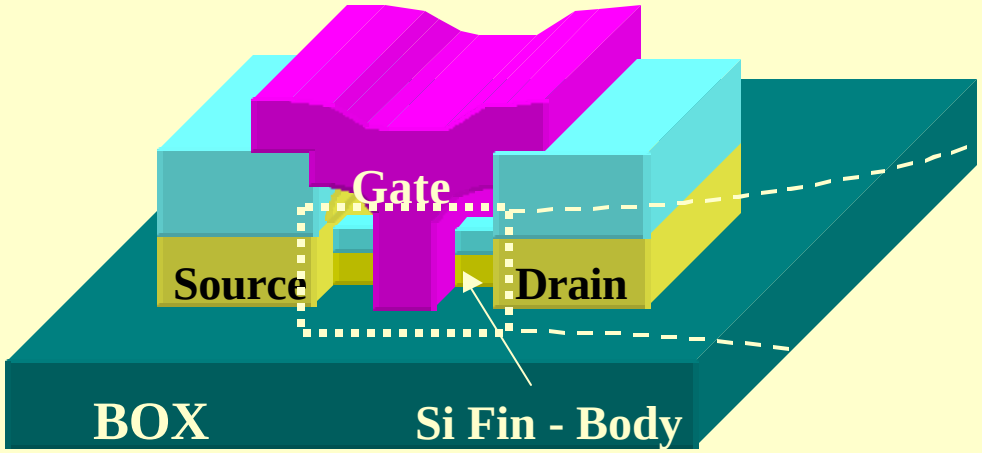
Why DARPA

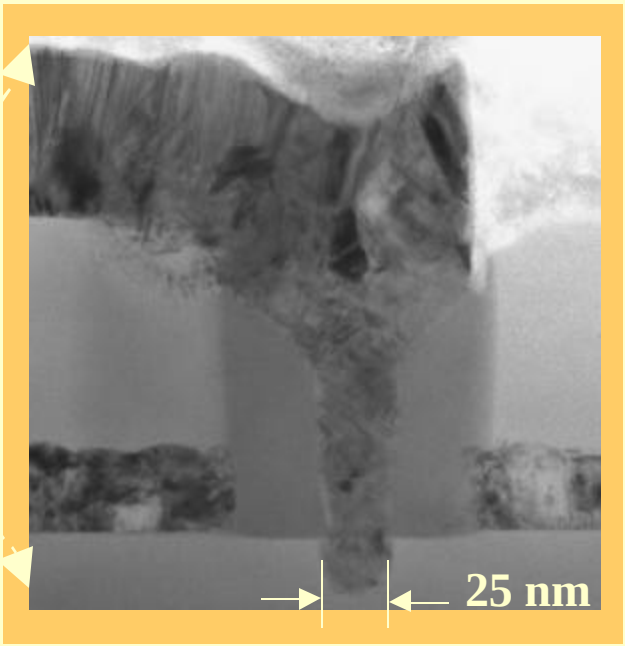
This is a basic research program that underpins many of the functional materials efforts in DSO

- **Nanoscience and Technology**
  - **Characterization of *buried interfaces and microstructures***
  - ***Readout of spin* information**
  - **Measurement and control of *single spins***
  - **Determination of *defects* and *doping profiles***
  - **Characterization of structure and function of *molecular devices***
  - **Characterization of *novel materials***
- **Biology**
  - **Rapid determination of *structure and function* of *any* bio-molecule or biomolecular complex (e.g. motors, channels)**
  - **Exploration of the *dynamics* of biological processes**

Graphic by L. J. Whitman, NRL

Nanoelectronics: 18-nm transistor



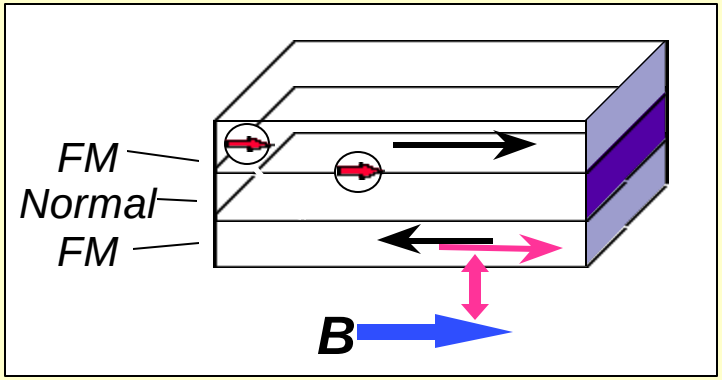


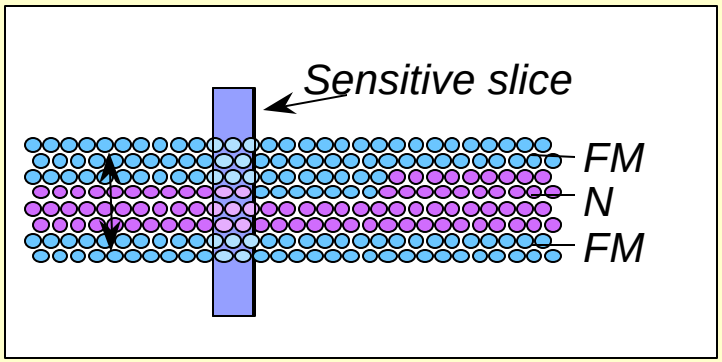
- Problem: **not reproducible!**
  - ***Random doping fluctuations*** become extremely important at nano scale:
    - $10^{18}/cm^3$ doping concentration $\Rightarrow$ one dopant atom per $(10nm)^3$!

Need atomic-scale characterization and control of doping profiles!

Buried Magnetic Interfaces

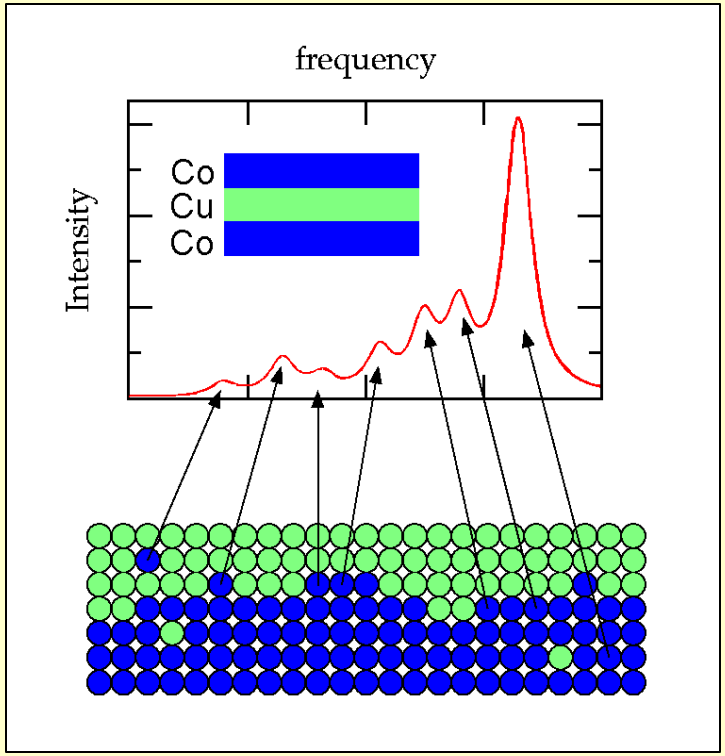
FMR: GMR Trilayer





The goal: spatial mapping of interlayer exchange coupling by FMR/MRFM.

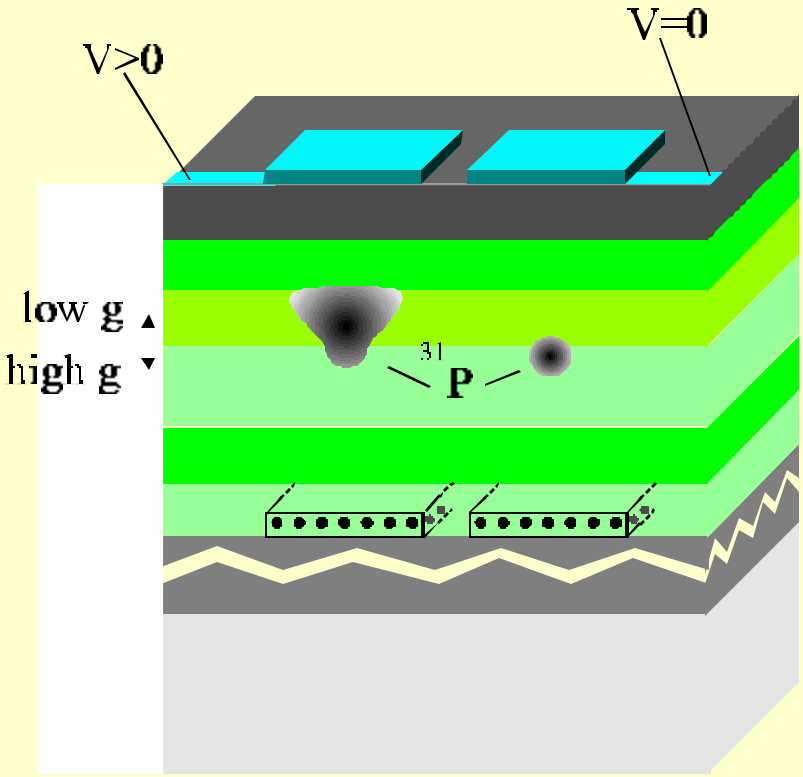
NMR: Co/Cu Interface

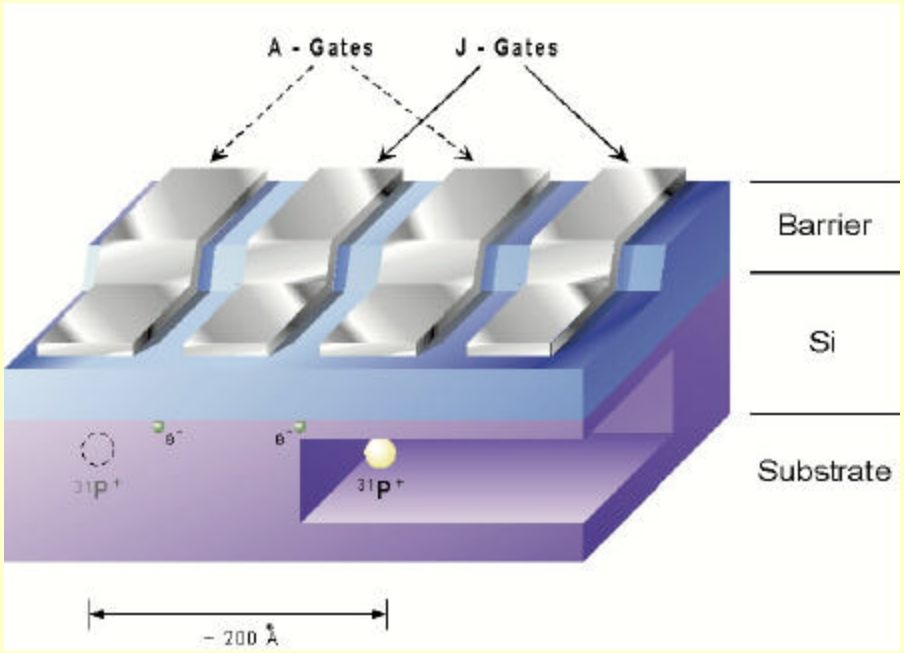


The goal: spatial mapping of interfacial magnetism by NMR/MRFM (Co nuclei).

Need atomic resolution interface information which no technique can currently provide.

Quantum Computing



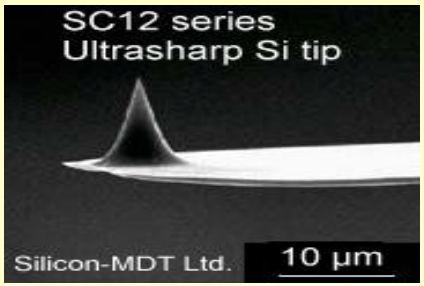


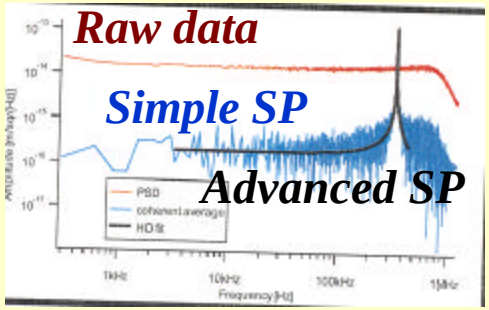
MRFM will enable:

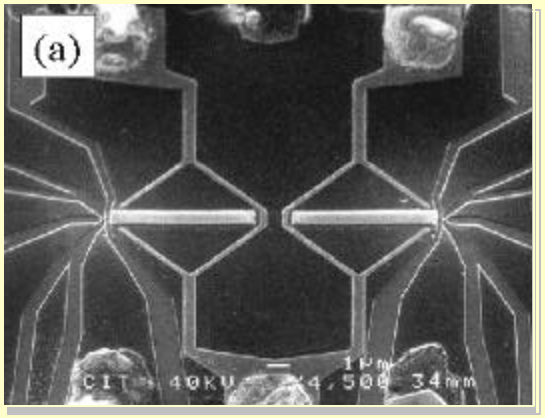
- ***Characterization and quality control*** of SS QC devices
- ***Readout*** of SS qubits

Major Issues

- **Nanofabrication**
  - Nanoscale cantilevers, nanotubes?
    - Optimum Q, high resonance frequency
- **Signal Processing and Control**
  - Very low SNR
    - Phase coded waveform
    - Highly efficient algorithms
    - Sensor array processing
  - Physics-based image formation
    - Generalized tomographic techniques
  - Control
    - Imaging-to-sensing feedback
- **Readout**
  - On-chip interferometric readout
  - Magnetic transduction
  - Readout arrays
- **High Temperature Operation**







- What MOSAIC is
  - A highly focused program to develop new imaging instrumentation with a prototype in 4 years
- What MOSAIC is not
  - A general research project on imaging, cantilevers, structural biology etc.
  - A project to provide improvements to existing instrumentation or techniques even if the improvements are significant

Meeting Purpose:

This meeting should facilitate the formation of multidisciplinary teams of physicists, materials scientists, engineers, molecular biologists, applied mathematicians and instrument builders to target the demonstration of single molecule imaging, imaging single defects in semiconductors and studying novel new materials.

Program Structure:

We anticipate selecting several teams pursuing the integrated development of prototype instruments as well as a very limited number of smaller efforts focused on advanced techniques such as novel readout or advanced signal processing algorithms.